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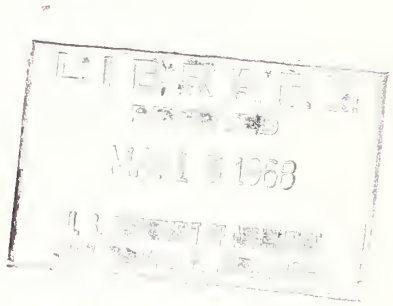
SHIPPING CONTAINERS
for
ICE-PACKED POULTRY—
EFFECT ON MICROBIAL COUNTS
and
WEIGHTS OF POULTRY AND ICE

Marketing Research Report No. 811



UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Research Service

PREFACE

This study is part of a broad program of research by the Market Quality Research and Transportation and Facilities Research Divisions of the Agricultural Research Service on technical problems in the marketing of poultry.

The Shorgood Poultry Co., Milford, Del., supplied facilities, and Sinclair-Koppers Co., Pittsburgh, Pa., supplied prototype polystyrene-foam boxes. T. R. Ryan and J. P. Anthony, U.S. Department of Agriculture, gave technical assistance in obtaining samples and performing laboratory work.

CONTENTS

	Page
Summary	3
Background	3
Purpose	4
Procedure	4
Common to all experiments	4
The four experiments	4
Results and discussion	6
Microbiological studies	6
Ice-retention studies	8
Carcass percentage weight loss	10
Weight changes of empty boxes	10
Temperature-rise studies	10
Conclusions	12

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SHIPPING CONTAINERS FOR ICE-PACKED POULTRY—EFFECT ON MICROBIAL COUNTS AND WEIGHTS OF POULTRY AND ICE

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SUMMARY

The effects of shipping container on changes in microbial counts, product weight, amount of ice needed, and tare weight of ice-packed fryer chickens were studied. Three types of containers were compared: Wirebound and corrugated fiberboard boxes—the two conventional shipping containers—and polystyrene-foam boxes—an experimental type made from 1-inch-thick-expanded polystyrene foam.

Major findings were as follows:

- When poultry was packed in 9.1 kg. of ice and held at 23.9° or 31.1° C. for 24 hours, fluid drainings from wirebound boxes had higher microbial counts than fluid from either of the other two types of containers.
- Poultry packed in 9.1 kg. of ice in wirebound boxes compared with poultry packed in 9.1 and 6.8 kg. of ice in polystyrene boxes and stored up to 13 days at 4.4° C. had higher microbial counts on breast skin.
- Poultry packed in 9.1 kg. of ice in fiberboard boxes and stored up to 13 days at 4.4° C. had higher microbial counts on breast skin than comparable lots in the polystyrene boxes.
- After 7 days of storage, correlations between microbial counts in fluid drainings from boxes and of carcass-breast skin were high, but difficulty in obtaining fluid from wirebound boxes in later stages of storage minimized the value in using counts in fluid to gage spoilage.
- When poultry was stored up to 6 days at 4.4° C., a greater percentage of ice was lost in wirebound than in fiberboard boxes, and a greater percentage of ice was lost in fiberboard than in polystyrene boxes.
- When poultry was stored up to 6 days at 4.4° C., the percentage of weight loss of carcasses was higher in wirebound than in fiberboard or polystyrene boxes.

BACKGROUND

Containers used for shipping ice-packed poultry from processing plants to central wholesale warehouses and retail stores are either wirebound or corrugated fiberboard boxes. Mountney,[1] citing information from the Package Research Laboratory,[2] indicated that advantages of the wirebound boxes are (1) ease of handling, (2) ease of stacking because of high-structural strength, (3) ease of packing because of the size and shape of box, (4) good ventilation and drainage of melted ice, and (5) resistance to moisture damage.

He also indicated that corrugated fiberboard boxes have the following advantages: (1) Tare weight is uniform; (2) boxes can be easily disposed of after use; (3) product can be removed before ice; and (4) water draining from upper boxes is less likely to drip into lower boxes in stacks.

May and others[3] found lower product weight loss and longer ice retention in wirebound boxes than in fiberboard boxes.

A third type of container for packaging chicken, constructed of 1-inch-thick-expanded polystyrene foam (henceforth referred to as polystyrene boxes), is being developed. Prototype boxes, made available by the manufacturer, were tested along

[1] MOUNTNEY, G. J. POULTRY PRODUCTS TECHNOLOGY. The AVI Publishing Company, Inc., Westport, Conn., p. 139. 1966.

[2] PACKAGE RESEARCH LABORATORY. SOME FACTORS AFFECTING POULTRY PACKAGING. Package Res. Lab. Bul. 378. Rev. 1962.

[3] MAY, K. N., POWELL, W. R., AND HUDSPETH, J. P. A COMPARISON OF QUALITY OF FRESH CHICKEN PACKED IN VARIOUS CONTAINERS. Ga. Agr. Expt. Sta. Bul. N. S. 168, 19 pp. 1966.

with the wirebound and fiberboard boxes. Generally, polystyrene boxes have advantages similar to those given for fiberboard. In addition, the polystyrene boxes have better insulation than either of the other two types. If less ice is needed in the polystyrene boxes than in the wirebound or fiberboard boxes, the use of polystyrene boxes could result in significantly lower shipping costs because, on a weight basis, a greater proportion of the payload would be the product.

Microbial growth, which causes off-odors and spoilage in unfrozen poultry, is retarded by low-product temperature during shipping and storage. By coating the surface areas of the carcass where the growth takes place, with melting ice, low temperatures are maintained even when air temperatures rise. Thus, retention of ice serves to delay rapid microbial growth and dehydration at the skin surface if the boxes of product are inadvertently exposed to high temperatures.

PURPOSE

The purpose of this study was to determine the effect of box type on changes in microbial counts, product and ice weight, and tare weight of boxes during storage of ice-packed fryer chickens. Both the acceptable storage temperatures of 2.2° and 4.4° C., and the abnormally high temperatures of 23.9° and 31.1° C. were included in these studies. The correlation between bacterial counts in the fluids accumulating in the boxes during storage and the counts on skin surfaces of the carcasses was also determined. In addition, information was obtained on temperature rise on the skin surface of chicken held in the boxes during exposure to high ambient temperatures.

PROCEDURE

These studies were conducted in a processing plant in Delaware and in storage facilities and laboratories at Beltsville, Md., in 1966 and 1967.

Common to All Experiments

The plant, in which samples were taken, normally packs chickens in wirebound boxes. Packed boxes were removed from the line at the point between the weighing scale and the icing operation. All birds contained wrapped giblets. Only boxes containing birds in the 1.0 to 1.1-kg. category were selected. The birds were removed from the boxes and repacked into the test boxes. When they were repacked, temperature in a deep portion of the breast meat of these birds was 5.8°±1.4° C.

The wirebound boxes used in the tests were wood veneer with parchment liner, with inside dimensions of 27 cm. high, 48 cm. long, and 42 cm. wide. The tare weight of wirebound boxes, when dry and empty, including parchment liner, was 2.32 kg., with a range from 2.10 to 2.75 kg.

The corrugated fiberboard boxes were of full-telescope design and were impregnated with a water-proofing resin wax. Inside dimensions of these boxes were 25 cm. high, 56 cm. long, and 36 cm. wide. Two 0.5- by 2.5-cm. drainage slots were in each end of the box, and a 0.5- by 7.5-cm. slot was in the center of the top cover. The tare weight of these boxes, when dry and empty, averaged 1.55 kg., with a range from 1.50 to 1.60 kg.

The polystyrene boxes were of part-telescope design and had inside dimensions of 24 cm. high, 60 cm. long, and 35 cm. wide. Sides, tops, and bottoms were about 2.5 cm. thick. The bottom of this box was molded with a slight pitch from the center toward the sides and from the center toward the ends, so that drainage would be directed toward the two 1.5-cm.-diameter drainage holes at the intersection of each end and the bottom. The average tare weight of these boxes, when dry and empty, was 0.65 kg., with a range from 0.63 to 0.68 kg.

The Four Experiments

Experiment 1.—To determine general level of microbial counts on the lots of eviscerated chickens at the processing plant 12 birds were sampled at the plant. The breast-swab method was used, wherein a 12.3-cm. circular area, delineated by a sterile circular fiber template held on the breast skin, was swabbed with a sterile cotton swab for 30 seconds; then the swab was placed aseptically into 99 ml. sterile 0.1 percent peptone.

Six samples of ice from the batches of crushed ice used at the plant were also examined microbiologically.

Six wirebound, six fiberboard, and 12 polystyrene boxes were each packed with 22 or 23 chickens or about 25 kg. of chicken. All carcasses were placed breast up, legs toward center, in two layers. One of six individually weighed carcasses was placed in each of the following locations in each box: In the upper layer—front left corner, front right corner, and back center; in the lower layer—back left corner, back right corner, and front center.

After each of the experimental boxes was packed, 9.1 kg. of crushed ice was added on top the poultry in each of the wirebound and fiberboard boxes and six of the polystyrene boxes; 4.5 kg. of crushed ice was added to each of the other six polystyrene boxes. All boxes were closed and placed into a mechanically refrigerated truck and transported the approximately 160 km. (100 miles) from the plant to the cold-storage facilities at

Beltsville, Md. Temperature in the truck was maintained at 4.5°±2.3° C. during the trip.

Upon arrival at Beltsville, all boxes were placed into a storage room at 0° C. and held there for 14 hours. Two wirebound, two fiberboard, and two polystyrene boxes, each with 9.1 kg. of ice, and two polystyrene with 4.5 kg. of ice were then placed into three temperature-controlled rooms for storage tests. One room was controlled at 3.3°± 0.5°, one at 23.9°±0.5°, and one at 31.1°±0.5°. Each type of box was stacked one on top of the other on wooden racks.

At the beginning and after 30, 72, and 144 hours of storage, the fluid in the top box in each stack in the 3.3° C. storeroom was sampled for microbiological examination. This fluid was obtained by tipping the boxes and collecting some of the fluid escaping from drain holes into sterile jars. At beginning and after 6 and 24 hours in the 23.9° and 31.1° rooms, the same procedure was followed. At the end of the storage period in each room (144 hours at 3.3°, and 24 hours at 23.9° and 31.1°), ice remaining in each box was weighed. The individual birds, which had been weighed in the plant, were reweighed, and the breast-skin surface of two birds in each box was swabbed for microbiological condition. At no time during storage was ice disturbed before being taken from each box to be weighed.

Serial dilutions were made from original samples, plated in duplicate in tryptone glucose yeast extract agar, and incubated at 20° C. for 72 hours.

The entire procedure was repeated a second time except that the temperature in the truck during the trip from the processing plant to the storage facilities was lower; it was maintained at −2.8°±3.8° C.

Experiment 2.—The same source, type, and size of birds and weight of birds per box were used as in experiment 1. In this experiment, which was replicated, 9.1 kg. of crushed ice was added to a wirebound box, a fiberboard box, and a polystyrene box; 6.8 kg. was added to a second polystyrene box, and 4.5 kg. to a third. The boxes were transported in the refrigerated truck at −2.8°±3.8° C. to Beltsville and placed immediately into a storage room at 4.4°±1.7°. The boxes were not stacked, but were placed individually on wire racks.

Fluid for microbial counts was taken from the wirebound box 5 and 7 days after processing, from the fiberboard and polystyrene box with 9.1 kg. of ice at 5, 7, 9, 11, 12, and 13 days, and from the polystyrene box with 4.5 or 6.8 kg. of ice at 5, 7, 9, and 11 days. Fluid was insufficient for microbiological examination from wirebound boxes after 7 days and from polystyrene boxes with either 4.5 or 6.8 kg. of ice after 11 days.

Microbial counts on breast-skin surface of a carcass in each box were determined 5, 7, 9, 11, 12, and 13 days after processing. Ice was not disturbed, nor were birds removed, when the carcasses were swabbed for microbiological examination. The only birds sampled were those whose breast areas were free of adhering ice. A different bird was sampled each sampling day. The number of days that ice remained in each box was determined.

Experiment 3.—A wirebound box, a fiberboard box, and a polystyrene box were each packed with about 25 kg. of fryer chicken as in other experiments. Thermocouples of a 20-point potentiometer recorder were inserted just under the skin of exposed portions of several carcasses in the top layer in each box, and were placed in the air surrounding each box. The boxes were placed in a temperature-controlled chamber, and the temperature of the contents of the chamber, including air, boxes, and chicken carcasses, were stabilized at 0.5°±0.5° C. The temperature of the air in the chamber surrounding the boxes was then raised as rapidly as possible (in less than ½ hour) to 23.9° ±0.5° C., and held at this temperature for 8 hours. Temperatures were recorded automatically throughout the 8-hour period. The procedure was repeated except that air temperature surrounding the boxes was raised to 32.2°±0.5° C.

Experiment 4.—The same source, type, and size of birds and approximate weight of birds per box were used as in the other experiments. The empty box, the poultry, and the ice added to each box were weighed before packing. In each of 18 wirebound and 18 fiberboard boxes 9.1 kg. of crushed ice was added on top the carcasses and 6.8 kg. of ice was added to each of 18 polystyrene boxes. The boxes were stacked three high and all boxes in each stack of the same type placed into a refrigerated truck. These boxes were then hauled at 1.1°±1.0° C. to the storage facility at Beltsville where they were placed immediately into a storage room at 4.4°±0.5°. Each box was placed in the same stack position in the storage room as it had been stacked in the truck. Wire racks held the bottom box of each stack about 2.5 cm. from the metal floor of the storage room. Stacks of each type of box were distributed throughout the storage room to minimize the effect of possible slight temperature variations in the air of the room.

After 2, 4, and 6 days of storage, two stacks of each of the three types of boxes were removed from the storage room, and the contents were removed. The empty box, the poultry, and the ice remaining from each box were weighed separately. After weighing, each box and contents were discarded; no boxes were repacked to be weighed again later.

Analyses of variance and multiple range test (Duncan's[4]) and correlation analysis were used when appropriate to evaluate the data.

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[4] DUNCAN, D. B. MULTIPLE RANGE AND MULTIPLE F TESTS. Biometrics 11: 1-7. 1955.

RESULTS AND DISCUSSION

Microbiological Studies

All microbial counts herein reported are expressed as the mean logarithm of the actual counts.

The microbial count on the breast skin of the chickens sampled at the processing plant was 3.88 ±0.36 (logarithmic mean ± standard deviation) per square centimeter for experiment 1, and 3.81 ±0.31 for experiment 2. The microbial count of the ice used for experiment 1 was 2.78±0.93 per milliliter, and for experiment 2, it was 2.89± 0.80.

Hereinafter, when type of container is mentioned, it is understood that all wirebound boxes and fireboard boxes were packed with 9.1 kg. of crushed ice; the amount of ice added to the polystyrene boxes varied and will be specified as results for specific experiments are described.

In experiment 1, since the period of storage differed at 3.3° C. from that at 23.9° and 31.1°, the microbial counts of the fluid in the boxes (table 1) for the 3.3° storage test were analyzed separately.

Analyses of variance and multiple range tests showed that, in experiment 1, the fluid of boxes stored for 144 hours at 3.3° C. had significantly higher counts ($p=0.05$) than those at the beginning and after 30 and 72 hours of storage at this temperature. There was no significant difference in fluid counts in boxes at the beginning or after 30 or 72 hours of storage, or as a function of box type.

The fluid from boxes stored for 24 hours at 23.9° and 31.1° C. had significantly higher counts ($p=0.01$) than that from boxes at the beginning or after 6 hours of storage (table 1). There was no significant difference at the beginning and after 6 hours of storage at these temperatures. Fluid in boxes stored at 31.1° had a significantly higher count ($p=0.01$) than that in boxes stored at 23.9°.

TABLE 1.—*Microbial counts in fluids accumulating in chicken-shipping boxes during specified storage period (experiment 1)* [1]

Storage room temp. (° C.) and box type	Ice added at packing (kg.)	Hours in storage room						Overall mean
		0	6	24	30	72	144	
3.3±0.5								
Wirebound	9.1	5.39			4.79	4.63	5.51	5.08
Fiberboard	9.1	4.41			3.92	3.81	4.83	4.25
Polystyrene	9.1	4.89			4.07	4.22	5.63	4.71
Polystyrene	4.5	4.53			4.59	5.07	5.63	4.96
Mean		4.81 a			4.35 a	4.43 a	5.40 b	4.75
23.9±0.5								
Wirebound	9.1	4.60	3.63	6.29				4.84
Fiberboard	9.1	4.49	3.59	4.57				4.22
Polystyrene	9.1	4.71	3.11	5.33				4.38
Polystyrene	4.5	4.95	4.11	5.09				4.71
Mean		4.69	3.61	5.32				4.54 a
31.1±0.5								
Wirebound	9.1	4.88	4.31	8.41				5.87
Fiberboard	9.1	4.23	3.81	6.63				4.89
Polystyrene	9.1	4.49	3.67	5.51				4.56
Polystyrene	4.5	4.35	4.34	7.25				5.31
Mean		4.49	4.03	6.95				5.16 b
Overall mean		4.66 a	3.82 a	6.13 b				

[1] Mean log of total organisms per millimeter (2 boxes). Means within a column or row followed by different letters are significantly different at the 5-percent level.

TABLE 2.—*Microbial counts on breast skin of chicken carcasses in shipping boxes after specified storage period (experiment 1)* [1]

Box type and position in stack	Ice added at packing (kg.)	Days in and temperature of storage			Overall mean
		1 at 23.9° C.	1 at 31.1° C.	6 at 3.3° C.	
Wirebound	9.1				
Top		3.73	5.63	4.24	4.53
Bottom		4.45	5.77	3.88	4.70
Mean		4.09	5.70	4.06	4.62 b
Fiberboard	9.1				
Top		4.67	3.89	3.60	4.05
Bottom		4.15	4.03	4.29	4.16
Mean		4.41	3.96	3.95	4.11 ab
Polystyrene	9.1				
Top		3.87	4.19	3.99	4.02
Bottom		4.27	4.51	3.89	4.22
Mean		4.07	4.35	3.94	4.12 ab
Polystyrene	4.5				
Top		3.73	4.02	3.84	3.86
Bottom		4.07	4.07	3.67	3.93
Mean		3.90	4.04	3.76	3.90 a
Overall mean		4.12 ab	4.51 b	3.93 a	

[1] Mean log of total organisms by swab method per square centimeter (4 birds). Means within a column or row followed by different letters are significantly different at the 5-percent level.

Mean logarithmic microbial count in fluid from wirebound boxes stored at 23.9° and 31.1° C. was 5.35; from fiberboard boxes, 4.55; from polystyrene boxes with 9.1 kg. of ice, 4.47; and from polystyrene boxes with 4.5 kg. of ice, 5.01. Fluid in wirebound boxes stored at 23.9° and 31.1° had a significantly higher count ($p=0.05$) than fluid in fiberboard boxes or in polystyrene boxes initially containing 9.1 kg. of ice, but did not differ significantly from fluid in polystyrene boxes in which only 4.5 kg. of ice had been added. Fluid microbial counts in the fiberboard and polystyrene with 9.1 kg. of ice and the polystyrene with 4.5 kg. of ice were not significantly different.

The breast skin of chickens stored 1 day at 31.1° C. had a significantly higher count ($p=0.05$) than that of chickens stored 6 days at 3.3° (table 2).

There was no significant difference between breast-skin counts on chickens stored 1 day at 23.9° C. and those stored 1 day at 31.1° nor between those stored 1 day at 23.9° and those stored 6 days at 3.3°.

The breast-skin count of chickens stored in wirebound boxes was significantly higher ($p=0.05$) than that of chickens stored in the polystyrene boxes packed with 4.5 kg. of ice. No other significant differences in breast-skin counts as a function of box type were found in this experiment.

In experiment 2 (table 3) chickens packed in polystyrene boxes with 9.1 kg. of ice had significantly lower breast-skin counts than chickens packed in either wirebound or fiberboard boxes. When 6.8 kg. of ice was used, counts of chickens in polystyrene boxes were significantly lower than those in wirebound boxes but not significantly different from those in the fiberboard boxes. The use of 4.5 kg. of ice in polystyrene boxes was less effective in controlling microbial growth during storage than the use of either 9.1 or 6.8 kg. of ice in this type of box. It was, however, as effective in controlling microbial growth as the use of 9.1 kg. of ice in either the wirebound or fiberboard box.

A pattern in the relation between breast-skin counts and fluid counts in experiment 2 was found in a series of correlation analyses (table 4). The correlations were highest when data from only the later stages of the 13-day storage period were included in the analyses; the correlation was very low when only data from the earliest stages in which samples were taken were included. These findings show that sampling fluids in shipping boxes for microbiological analysis can give an accurate indication of the microbiological condition of the chicken in boxes only in the later stages of storage (after a week at 4.4° C., for example).

TABLE 3.—*Microbial counts on breast skin of chicken carcasses* [1] *and in fluids accumulating in bottom* [2] *of shipping boxes during storage at 4.4° ± 1.7° C. (experiment 2)*

Box type and source of sample	Ice added at packing (kg.)	Days stored						Mean [3]	Ice melting time (days)
		5	7	9	11	12	13		
Wirebound	9.1	------	------	------	------	------	------	--------	6.0
Breast skin	--------	3.67	3.99	7.01	7.82	8.03	8.63	6.53 c	----------
Fluid	--------	7.43	8.78	------	--------	------	--------	--------	----------
Fiberboard	9.1	------	------	------	--------	------	--------	--------	7.0
Breast skin	--------	3.91	4.38	5.08	8.04	6.80	8.71	6.15 bc	----------
Fluid	--------	5.89	7.95	9.38	9.97	9.94	10.88	--------	----------
Polystyrene	9.1	------	------	------	--------	------	--------	--------	11.5
Breast skin	--------	3.45	3.79	4.03	5.39	5.75	8.33	5.12 a	----------
Fluid	--------	5.58	6.25	8.87	9.67	9.73	10.32	--------	----------
Polystyrene	6.8	------	------	------	--------	------	--------	--------	8.0
Breast skin	--------	4.19	4.03	4.33	5.82	7.38	8.51	5.71 ab	----------
Fluid	--------	5.07	6.91	9.05	9.75	------	--------	--------	----------
Polystyrene	4.5	------	------	------	--------	------	--------	--------	6.0
Breast skin	--------	3.59	4.57	6.44	7.67	7.97	9.28	6.59 c	----------
Fluid	--------	5.37	7.41	9.58	10.04	------	--------	--------	----------
Breast-skin mean [3]	--------	3.76 a	4.15 a	5.38 b	6.95 c	7.19 c	8.69 d	--------	----------

[1] Mean log of total organisms by swab method per square centimeter (2 birds).
[2] Mean log of total organisms per milliliter (2 boxes).
[3] Means within a column or row followed by different letters are significantly different at the 5-percent level.

The usefulness of counts found in fluid drainings as an indicator of microbiological condition of the carcass is minimized further since it is difficult, if not impossible, to obtain this fluid for more than a day or two after the ice has melted in wirebound boxes because of the rapid dehydration occurring in these boxes. In the fiberboard boxes used in these experiments, however, the bottoms of the boxes bowed downward during storage, allowing fluids to accumulate in a pool, which provided a ready source for sampling fluids for the entire storage period.

TABLE 4.—*Correlation analysis between microbial counts on breast skin and counts in fluids accumulating in shipping boxes during storage at 4.4° ± 1.7° C. (experiment 2)*

Data included in correlation		r	Significance level (percent)
Days of storage	Box types [1]		
5, 7, 9, 11, 12, 13	A, B, C, D, E	0.776	0.1
5, 7	A, B, C, D, E	.335	n.s.
5, 7, 9, 11	B, C, D, E	.742	.1
5, 7, 9, 11, 12, 13	B, C	.820	.1
9, 11, 12, 13	B, C, D, E	.887	.1

[1] A—wirebound; B—fiberboard; C—polystyrene with 9.1 kg. of ice; D—polystyrene with 6.8 kg. of ice; and E—polystyrene with 4.5 kg. of ice.

Ice-Retention Studies

In experiment 1 (table 5), significantly less ice ($p=0.01$) was retained in wirebound boxes and in the polystyrene boxes with 4.5 kg. of ice than in the fiberboard boxes. The fiberboard boxes, however, retained significantly less ice than the polystyrene boxes with 9.1 kg. of ice. Significantly less ice ($p=0.01$) was retained after 1-day storage at 31.1° C.

Significantly less ice ($p=0.01$) was retained in the top boxes (0.93 kg.) than in the bottom boxes (1.51 kg.) of the stacks.

When data of experiment 1 were analyzed on the basis of "percentage loss of ice," the same pattern and extent of differences were found as had been found when analyses were on the basis of "amount remaining."

In experiment 2, the period of storage was sufficiently long so that no ice remained in any box at the termination of the experiment. As may be seen in table 3, however, polystyrene boxes with 9.1 kg. of ice retained ice for the longest period, followed by polystyrene boxes with 6.8 kg. of ice, fiberboard boxes, and finally wirebound and polystyrene boxes with 4.5 kg. of ice.

In experiment 4 (table 6), significantly less ice ($p=0.01$) was retained in the wirebound boxes than in either the fiberboard box or the polystyrene with 6.8 kg. of ice. The last two types were not significantly different. Significantly less ice ($p=0.01$) remained after 6 days of storage than

TABLE 5.—*Ice remaining on chicken carcasses in shipping boxes after specified storage period (experiment 1)* [1]

Box type and stack position of box	Ice added at packing (kg.)	Days and temperature (° C.) of storage			Overall mean
		1 at 23.9° C.	1 at 31.1° C.	6 at 3.3° C.	
		Kg.	*Kg.*	*Kg.*	*Kg.*
Wirebound	9.1				
Top		0	0	0.3	0.1
Bottom		.2	0	1.8	.7
Mean		.1	0	1.1	.4 a
Fiberboard	9.1				
Top		.3	0	1.4	.6
Bottom		1.4	.5	2.4	1.4
Mean		.9	.2	1.9	1.0 b
Polystyrene	9.1				
Top		3.4	1.7	3.2	2.8
Bottom		4.7	2.6	4.0	3.7
Mean		4.1	2.1	3.6	3.3 c
Polystyrene	4.5				
Top		.4	0	.3	.2
Bottom		.3	.1	.3	.2
Mean		.3	0	.3	.2 a
Overall mean		1.3 b	.6 a	1.7 c	

[1] Mean of 2 boxes. Means within a column or row followed by different letter are significantly different at the 1-percent level.

TABLE 6.—*Ice remaining on chicken carcasses in shipping boxes after storage at 4.4°±0.5° C. (experiment 4)* [1]

Box type and stack position of box	Ice added at packing (kg.)	Days stored			Overall mean
		2	4	6	
		Kg.	*Kg.*	*Kg.*	*Kg.*
Wirebound	9.1				
Top		2.1	0.4	0	0.9
Middle		3.3	1.4	0	1.6
Bottom		2.9	1.6	0	1.5
Mean		2.8	1.1	0	1.3 a
Fiberboard	9.1				
Top		4.5	1.5	.2	2.1
Middle		5.4	3.3	1.2	3.3
Bottom		4.9	2.7	1.3	2.9
Mean		4.9	2.5	.9	2.8 b
Polystyrene	6.8				
Top		3.6	2.0	.1	1.9
Middle		4.2	3.1	.7	2.7
Bottom		3.9	2.8	1.1	2.6
Mean		3.9	2.6	.6	2.4 b
Overall mean		3.9 c	2.1 b	.5 a	

[1] Mean of 2 boxes. Means within a column or row followed by different letters are significantly different at the 1-percent level.

after 4 for all types, and less after 4 days than 2. Significantly less ice ($p=0.01$) was retained in the top boxes (1.61 kg.) than in the middle (2.50 kg.) or bottom boxes (2.35 kg.) of the stacks. There was no significant difference in ice retention between the middle and bottom boxes.

Because less ice was added to the polystyrene boxes than to wirebound and fiberboard boxes at time of packing for experiment 4, an analysis of significance of differences in percentage loss of ice was made. The same pattern and extent of differences were found as when the analysis had been made on the basis of amount of ice remaining, except that analyzing for percentage loss showed a significantly greater loss ($p=0.05$) in fiberboard than in polystyrene boxes.

Carcass Percentage Weight Loss

The percentage weight loss of individual carcasses in specific locations within boxes is summarized in table 7. Carcasses surrounded by other carcasses lost the least weight during shipping and storage.

The percentage weight loss of carcasses in experiment 4 stored at 4.4° C. (table 8) was significantly greater ($p=0.05$) in wirebound boxes than in either fiberboard or polystyrene boxes. Weight loss of carcasses in fiberboard and polystyrene boxes were not significantly different. Percentage weight loss was significantly less ($p=0.05$) after 4 days than after 2 or 6 days of storage. There was no significant difference in percentage weight loss between chicken stored 2 days and chicken stored 6 days. Stack position had no significant effect on carcass percentage weight loss.

Weight Changes of Empty Boxes

After storage for 2, 4, and 6 days at 4.4° C., the average percentage gain in weight ($p=0.01$) of the boxes without contents was greatest for wirebound boxes, intermediate for fiberboard, and least for polystyrene boxes (experiment 4—table 9). Boxes stored 4 days gained significantly more ($p=0.05$) than those stored 2 days, while those stored 6 days did not gain significantly more than those stored 4 days.

The top boxes exhibited less percentage gain in weight (20.18) ($p=0.01$) than either the middle (29.49) or bottom boxes (28.50) of the stacks. Percentage weight gain between middle and bottom boxes was not significantly different.

Temperature-Rise Studies

As may be seen in figure 1, the skin surface temperature of the chicken carcasses in the polystyrene box remained below 10° C. for a period about twice as long as that of the carcasses in the wirebound or fiberboard box. This was true for either 23.9° or 32.2° C. ambient temperature conditions. The fiberboard box was somewhat superior to the wirebound box in retaining low temperatures.

TABLE 7.—*Weight loss of chicken carcasses in shipping boxes as affected by position of the carcasses within the boxes (experiment 1)*

Position in shipping boxes	Mean loss in weight [1]
	Percent
Lower layer—front middle	3. 95 a
Upper layer—back middle	4. 10 ab
Lower layer—back right	4. 60 abc
Upper layer—front left	4. 75 bc
Lower layer—back left	5. 20 c
Upper layer—front right	5. 30 c

[1] Means followed by different letters are significantly different at the 5-percent level.

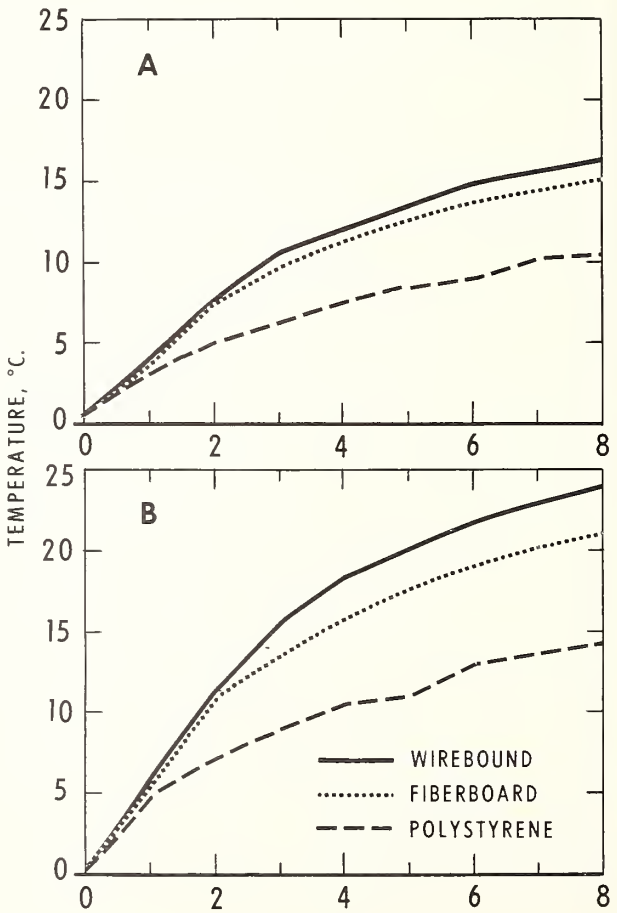

FIGURE 1.—Temperature change of skin surface of top layer of fryer chickens (initial temperature 0.5° C.) in shipping boxes during holding at (*A*) 23.9° and (*B*) 32.2° C.

TABLE 8.—*Weight loss of chicken carcasses in shipping boxes after storage at 4.4° ±0.5° C. (experiment 4)* [1]

Box type and stack position of box	Ice added at packing (kg.)	Days stored			Overall mean
		2	4	6	
		Pct.	*Pct.*	*Pct.*	*Pct.*
Wirebound	9. 1				
Top		4. 1	3. 7	4. 5	4. 1
Middle		3. 6	2. 5	3. 5	3. 2
Bottom		3. 5	3. 2	3. 5	3. 4
Mean		3. 7	3. 1	3. 9	3. 6 b
Fiberboard	9. 1				
Top		3. 3	2. 4	3. 0	2. 9
Middle		3. 2	2. 3	3. 4	3. 0
Bottom		2. 6	2. 7	3. 8	3. 0
Mean		3. 1	2. 5	3. 4	3. 0 a
Polystyrene	6. 8				
Top		3. 0	2. 9	2. 8	2. 9
Middle		3. 0	3. 1	3. 0	3. 1
Bottom		3. 6	3. 3	3. 2	3. 4
Mean		3. 2	3. 1	3. 0	3. 1 a
Overall mean		3. 3 b	2. 9 a	3. 4 b	

[1] Mean of 2 boxes. Means within a column or row followed by different letters are significantly different at the 5-percent level.

TABLE 9.—*Weight gain of shipping boxes without contents after storage at 4.4° ±0.5° C. (experiment 4)* [1]

Box type and stack position of box	Ice added at packing (kg.)	Days stored			Overall mean
		2	4	6	
		Pct.	*Pct.*	*Pct.*	*Pct.*
Wirebound	9. 1				
Top		35. 5	25. 9	38. 0	33. 1
Middle		47. 5	58. 0	60. 4	55. 3
Bottom		43. 3	65. 2	52. 6	53. 7
Mean		42. 1	49. 7	50. 3	47. 4 c
Fiberboard	9. 1				
Top		14. 1	21. 9	23. 7	19. 9
Middle		15. 8	25. 1	26. 9	22. 6
Bottom		17. 7	23. 7	25. 7	22. 4
Mean		15. 9	23. 6	25. 4	21. 6 b
Polystyrene	6. 8				
Top		6. 9	7. 8	7. 9	7. 5
Middle		7. 7	10. 1	13. 9	10. 5
Bottom		7. 7	7. 7	12. 9	9. 4
Mean		7. 4	8. 5	11. 5	9. 2 a
Overall mean		21. 8 a	27. 3 b	29. 1 b	

[1] Mean of 2 boxes. Means within a column or row followed by different letters are significantly different at the 1-percent level.

CONCLUSIONS

The retention of ice and concomitant low temperature suppresses microbial growth on ready-to-cook chickens during holding periods. Shipping boxes with good insulation properties protect the product from rapid spoilage in two ways: First, by retaining ice for a longer period during extended low temperature unfrozen storage; and second, by minimizing the effect of any accidental exposure to high temperatures during shipping and handling.

The dehydration that occurs when skin and cut surfaces of unfrozen poultry are exposed to air is probably the most important cause of weight loss in the later stages of the holding period, after most of normal draining of free moisture has occurred. Retaining a covering of ice and restricting free airflow in the shipping box would reduce this source of weight loss of the product.

Retention of ice in shipping boxes is obviously influenced by temperature of the product at the time ice is added at the processing plant. If product temperature is much above 0° C., and if refrigerated shipping and storage temperatures are near or below 0° immediately after packing, ice-melting rate could be expected to increase more rapidly in well-insulated boxes than in poorly insulated ones. In well-insulated boxes, the ice provides most of the cooling effect to lower the temperature of the product, and the cooling provided by the storage or shipping facility does not contribute as significantly.

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